

eRHIC e⁺/e⁻ Injector Systems

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Outline

- Design considerations / Requirements
- Polarized source options
 1. Mode locked laser
 2. CW high power diode laser
- Accelerator options
 1. Recirculating NC linac
 2. Recirculating SC linac
 3. Figure 8 booster synchrotron
- Positrons
- Conclusions

Design considerations

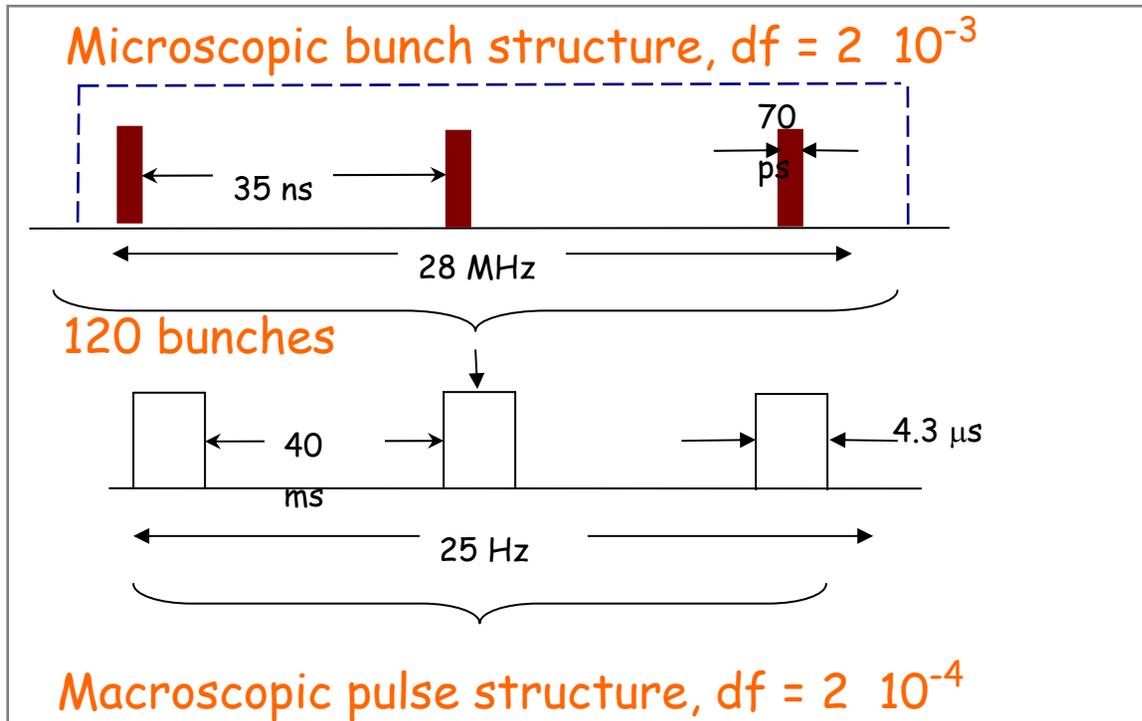
The injector should NOT limit the performance of the main ring:

- Inject polarized electrons/ unpolarized positrons
- Maintain maximum current, 450 mA
- Preserve highest polarization >70%
- Bunch structure 35 ns spacing, uniformity < 1%
- Flexibility in patterns, unpopulated bunches

Most straightforward technique is to inject at full energy, 5 - 10 GeV

- Main ring at fixed energy
- Rapid filling (~10 min.) and top-off mode possible
- Preserve polarization from source

Time Structure



Stack many pulse trains (15000) of 1.3 pC bunches at 25 Hz rates over 10 minutes to fill electron ring.

Polarized injector options

Option 1: Mode locked laser

All bunch manipulations and synchronizations are made on the laser light before directed to the photocathode.

No chopping and bunching of the electron beam may be necessary (J-lab, G0 Experiment).

Option2: CW high power diode laser

Quasi CW laser light (4.3 μ s long) produces photoemission of polarized electrons.

All pulse manipulation, synchronizations are made on the electron beam using chopper and bunchers (MIT-Bates)

Mode locked laser

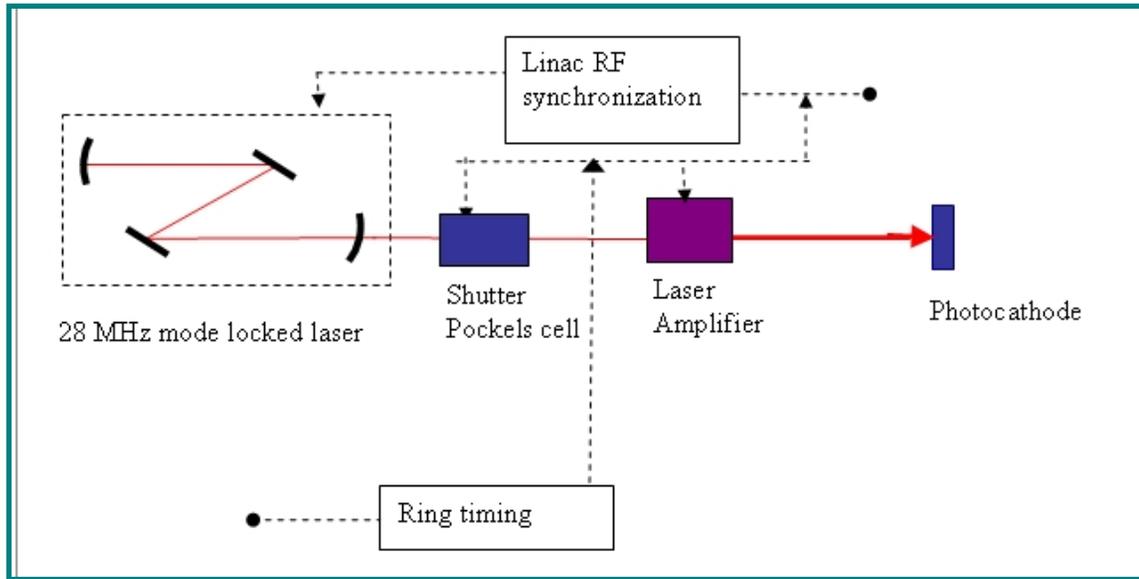


Figure 4. Schematic diagram of mode locked laser option for the eRHIC electron injector.

J-lab 60 laser:
 $P_{\text{peak}} = 150 \text{ W}$



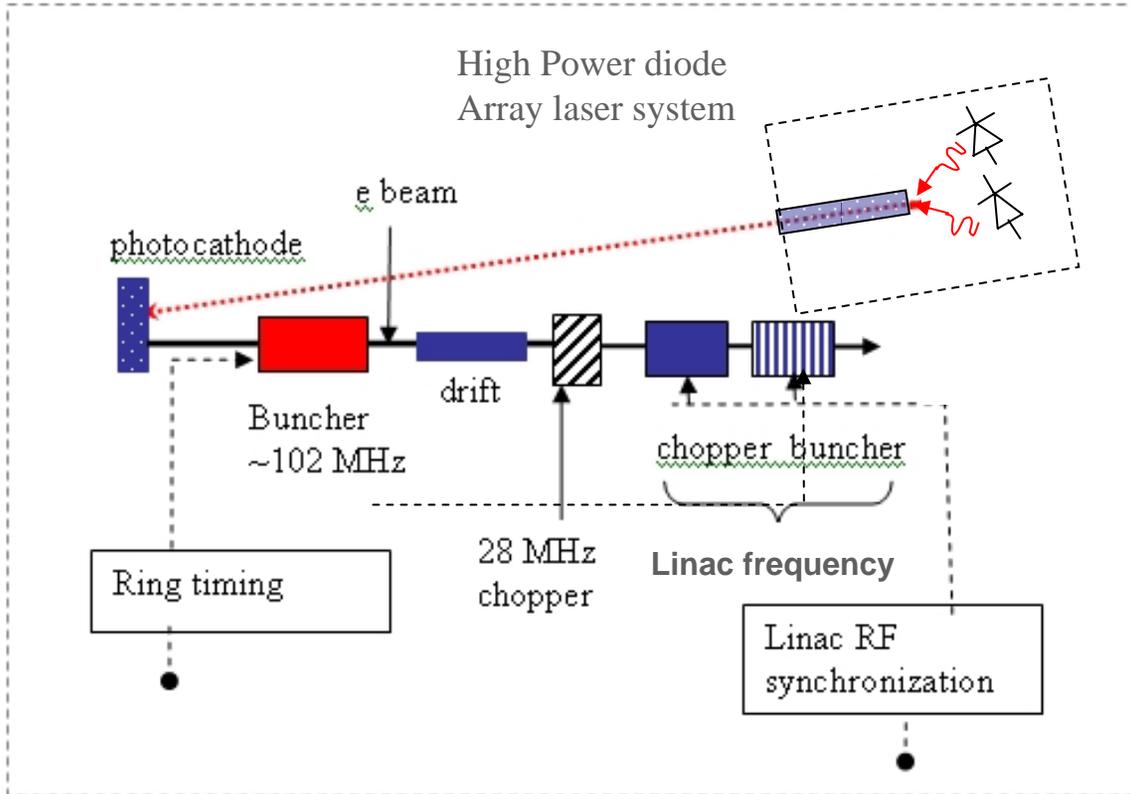
Time Bandwidth laser

For ring $I_{\text{av}} = 450 \text{ mA}$, need
 $I_{\text{peak}} = 18 \text{ mA}$ from injector

→ $P_{\text{peak}} = 50 \text{ W}$

- Seems there is enough laser power. Need some R&E to test such lasers for this application. Surface charge limit and lifetime.

CW high power diode laser



MIT-Bates system

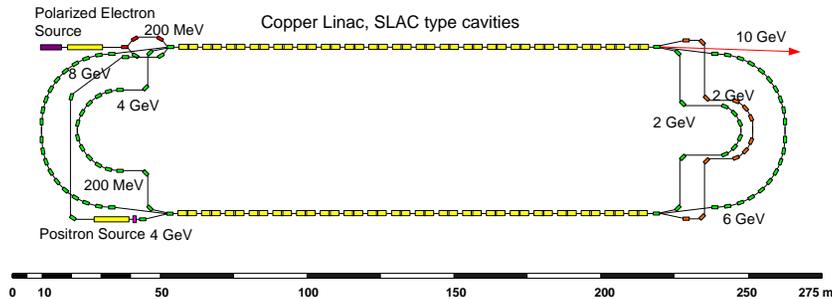
$P_{peak} = 150 \text{ W CW-1 kHz}$

$$I_{inj} = \frac{I_{linac}}{\epsilon_{cap}} \times F_{bunching}$$

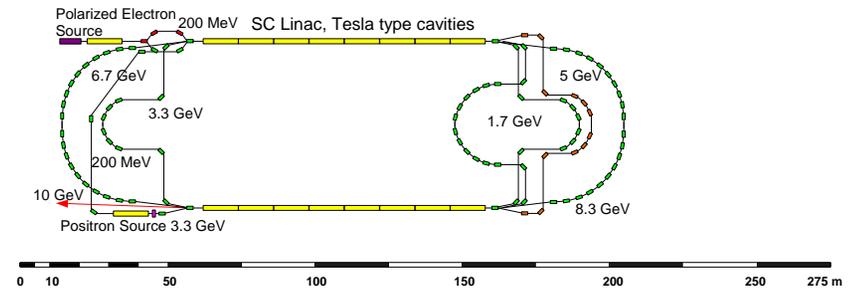
$F_{bunch} \sim 2-10$, $\epsilon_{cap} \sim 0.5$ at Linac frequency $\longrightarrow I_{inj} \sim 2-20 \text{ mA}$

Need more work on the 102 MHz bunching.

Full energy injection options



Recirculating NC linac



Recirculating SC linac

- Injection of polarized electrons from source
- Ring optimized for maximum current
- Top-off

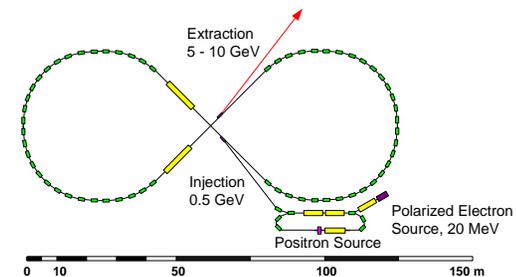
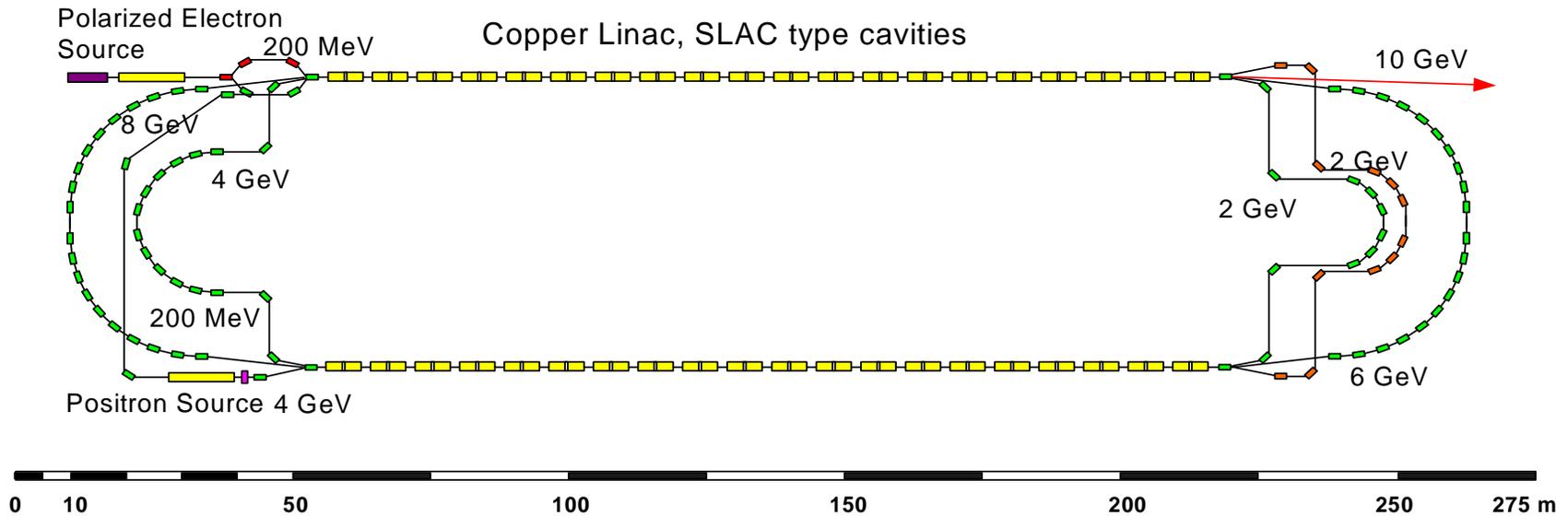


Figure 8 booster synchrotron

Recirculating NC linac



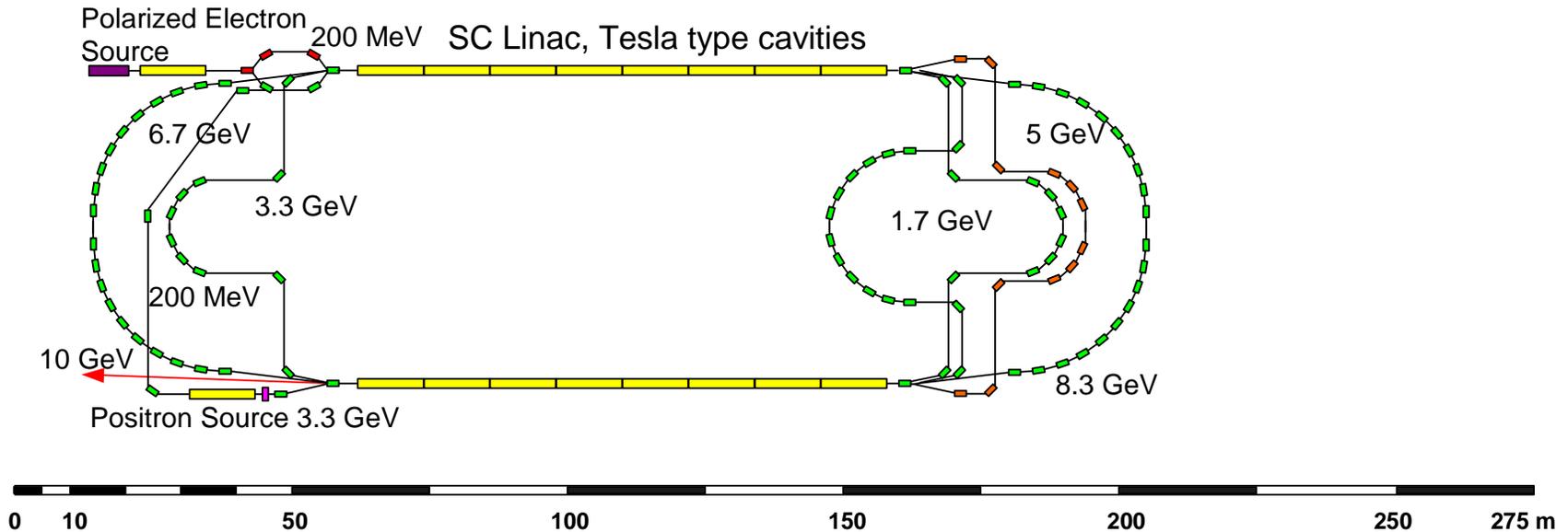
- 3 m SLAC 2856 MHz traveling wave acc. sections
- Accelerator and RF commercially available
- Known technology, solid design

NC linac, parameters

Linac Frequency	2856 MHz
Linac Gradient	16 MV/m
Number of Linacs	2
Active Linac Length	120 m
Linac Length	170 m
Linac Section Length	3 m
Shunt Impedance	53 MOhm/m
RF Input Power/Section	25 MW
RF Macropulse Length	10 μ s
Beam Pulse Length	2 μ s
Macropulse Current	0.1 mA
Pulse Repetition Rate	30 Hz

Section Fill time	0.820 μ s
Klystron Power	50 MW
Klystron Current	350 A
Klystron Voltage	350 kV
Klystrons/Modulator	1
Accelerating Sections/Klystron	2
Number of Sections	80 (40/Linac)
Number of Klystrons	40 (20/Linac)

Recirculating SC linac



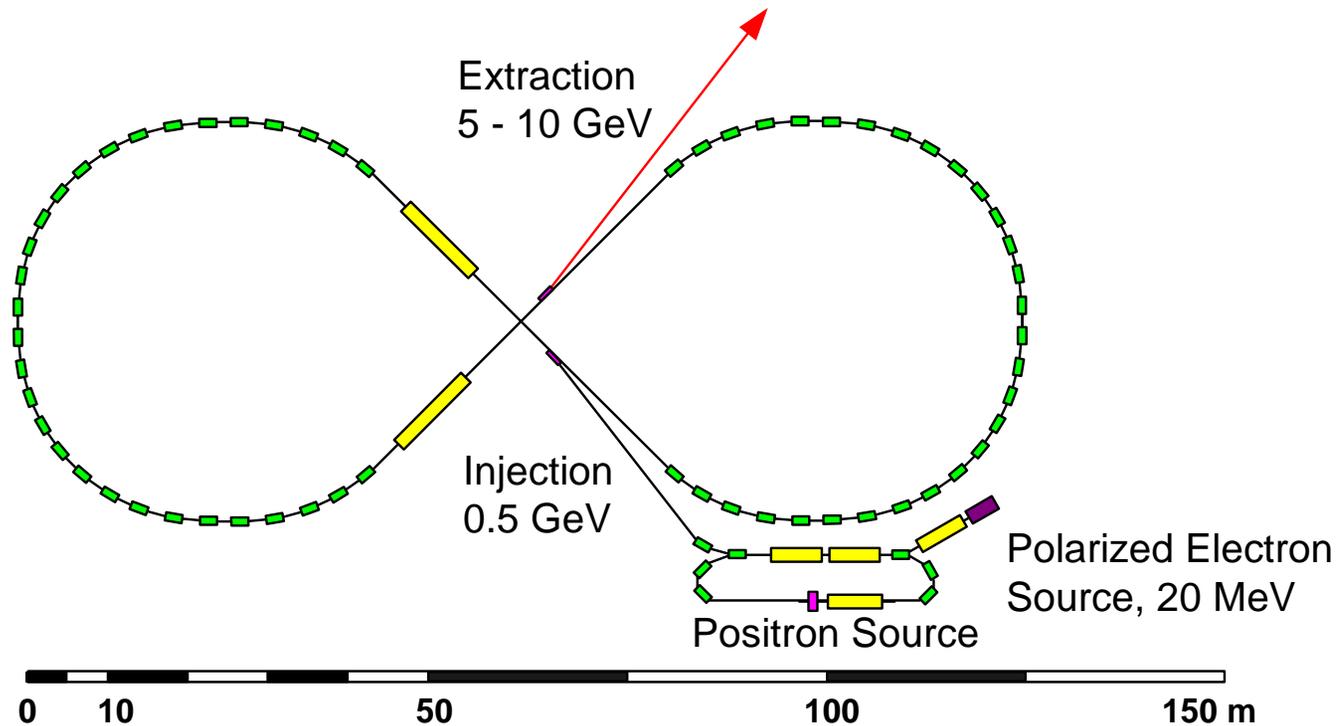
- 1 m TESLA 1300 MHz RF cavities
- 8 cavities / cryomodule
- Due to positron losses damping ring likely needed

SC linac, parameters

Linac Frequency	1300 MHz
Linac Gradient	26 MV/m
Number of Linacs	2
Active Linac Length	64 m
Linac Length	92 m
Linac Cavity Length	1 m
Shunt Impedance (R/Q)	1038 Ohm
Cavities/Cryomodule	8

RF Macropulse Length	40 ms – CW
Average Macropulse Current	0.01 μ A
RF Pulse Repetition Rate	CW – 10 Hz
External Coupling (Q_{ext})	$2-10 \cdot 10^{+7}$
Cavity Fill time	1-4 ms
Klystron Power/Cavity	<10 kW
Cavities/Klystron	1
Maximum Heat Load at 2K	5 kW (CW)
Average Heat Load at 2K	
<ul style="list-style-type: none"> • 10 minute fill every 8 hrs • 10 sec top up every 10 min 	100 W 80 W

Figure 8 booster synchrotron

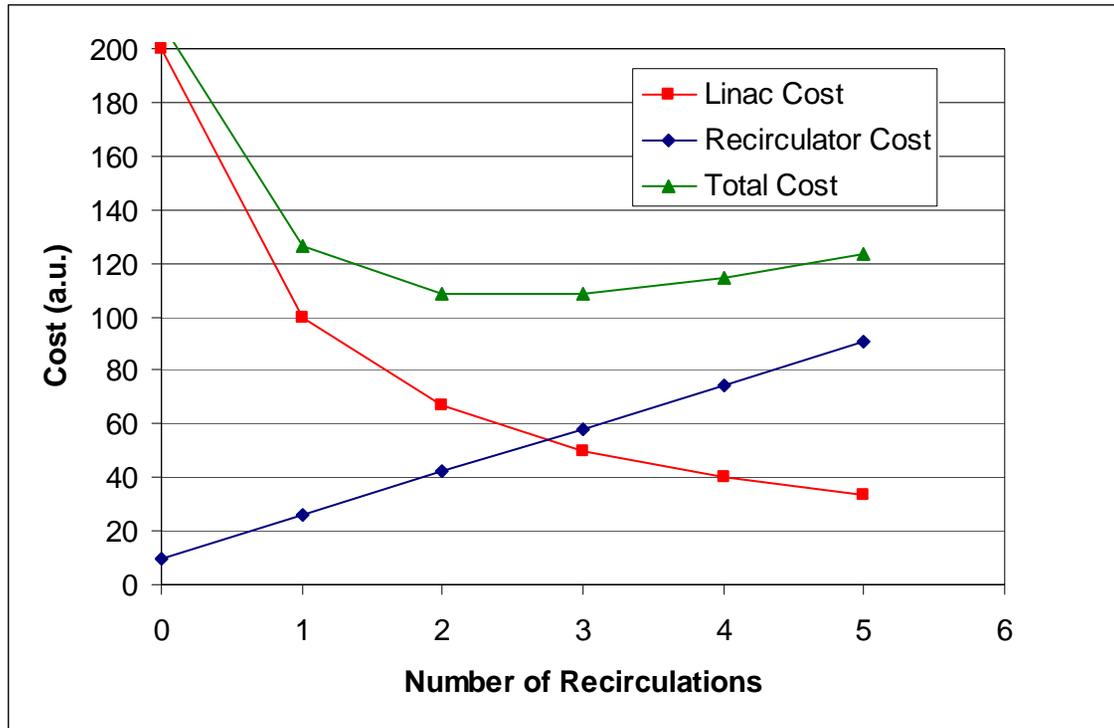


- Cost effective
- Spin precession cancelled, no resonance crossing
- Needs detailed studies of polarization during ramp

Figure 8 Synchrotron Parameters

Maximum Energy	10 GeV
Injection Energy	500 MeV
Circumference	500 m
Dipole Curvature	30 m
Synchrotron Radiation Losses / Turn	47 MV @ 10 GeV
Accelerated Current	1 mA
Peak Beam Power @ 10 GeV	50 kW
Installed RF Voltage	75 MV
Installed RF Power	100 kW
Synchrotron Cycling Frequency	<60 Hz
Polarization Damping Time	40 s
Equilibrium Polarization	0

Costs estimates (SC linac)



Positron production

	SLC 94	NC Linac	SC Linac	Figure 8
Electron Drive Beam				
Energy (GeV)	30	4	3.3	0.5
Pulse Charge (nC)	5.6	2	4	20
Pulse Width (us)	Single Bunch	2	4	2
Repetition Rate (Hz)	120	30	30	60 (Linac freq)
Beam Energy / Pulse (J)	160	8	13	10
Avg. Beam Power (kW)	20	0.24	0.4	1.2
Positron Yield/e-	2.4	~0.1	~0.1	~0.01

Requirements for positron production are relatively modest with respect to SLC

Summary

- Polarized source, 20 mA, $P > 70\%$, bunch structure
 1. Mode locked laser: Precise timing synchronization of the laser.
 2. Precise timing of the chopping/bunching of the e beam.
- Accelerator, 5 - 10 GeV
 1. Ring fill to 450 mA in 10 minutes.
 2. Polarized electrons, positrons
 3. Top-off.
- Luminosity $0.4 \cdot 10^{33} \text{ cm}^{-2}\text{s}^{-1}$
- 0th order design well understood / existing techniques
- Ready for preparing CDR/TDR